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TUNA FISHING IN PALAU WATERS

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 42

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

EXPLANATORY NOTE

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Washington, D. C.
January 1951

United States Department of the Interior
Oscar L. Chapman, Secretary
Fish and Wildlife Service
Albert M. Day, Director

Special Scientific Report - Fisheries
No. 42

TUNA FISHING IN PALAU WATERS

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Pacific Oceanic Fishery Investigations

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1/ South Sea Fishery News [Nanyō Suisan Jōhō], Vol. 6, No. 1, pp. 7-9. March 28, 1942.

2/ South Sea Fishery News [Nanyō Suisan Jōhō], Vol. 5, No. 2, pp. 2-6. 1941.

3/ South Sea Fishery News [Nanyō Suisan Jōhō], Vol. 6, No. 1, pp. 10-13. March 28, 1942.

4/ Fisheries Research Station Progress Report No. 1, 1923-1935. South Seas Government-General, Palau, December 1937. pp. 27-37.

5/ South Sea Fishery News, Vol. 5, No. 4, pp. 2-4. September 2, 1941.

Report of

Grounds Fished by Tuna Boats Operating in the Inner South Seas

About 1939 the main fishing grounds of tuna boats from Japan operating in the waters around the South Sea Islands were in the area centered at east longitude 145° and from north latitude 4° to 10°. Thereafter they shifted gradually eastward and centered at east longitude 150° and north latitude 1° - 2° to 5° - 6°. Beginning around January and February of this year the latitude moved southward, whereas the longitude remained nearly the same as before. The main fishing ground about April was in the neighborhood of 1° south latitude, and it was rumored that the fishing boats crossed the equator to carry on their fishing. It then moved gradually northward and the main fishing grounds were located between north latitudes 0° and 3° again about June. The longitude remained about the same, mainly between 150° and 155°, and some fishing boats even went out as far as 160°. With the exception of the fishing grounds in the south latitude below the equator, the fishing grounds are usually centered in the equatorial countercurrent, although they may shift east and west. The fact that yellowfin tuna occupies the top of the list of fish caught is encouraging in that it indicates that a large number of yellowfin tuna inhabit the equatorial countercurrent. The author considers that the fact that the fishing boats passed through the countercurrent and proceeded to the distant south latitudes to conduct their operations was an unavoidable temporary measure due to the poor fishing caused by abnormalities in the countercurrent. Let me explain briefly.

This author and others, who made oceanographic studies of the waters adjacent to Palau over a period extending through January, February, and March of this year, were truly startled to see that oceanographic conditions were abnormal. In short, the results showed that the surface water temperature of numerous offshore areas had fallen to 27°, and that the water temperature of the 100-meter stratum, which has a close bearing upon the occurrence of yellowfin tuna, had a low average temperature of 18.5° even in the countercurrent. This had a very bad effect upon fishing in the adjacent seas and there was unusually poor skipjack fishing off the shores of Palau. Tuna fishing along the coast and on the seas also slackened markedly and only a few tuna were caught even in the equatorial countercurrent. (See "Oceanographic Changes and Fishing Conditions in Palau Waters," South Seas Fishery News, Vol. 5, No. 2.)

At this time the author made a comparative examination of the results during various seasons of the research vessels and fishing boats from Japan which were operating in the neighborhood of 150°. He discovered the fact that fishing was slack even in this area during practically the same period. It was eventually surmised that the adverse conditions seen in the waters adjacent to Palau exist not only here, but extend to the areas far to the east. Thereafter numerous data on tuna fishing conditions in the vicinity of 150° and skipjack fishing conditions during the early part of this year at Truk and Ponape were assembled. When these were studied, it became clear that during the slack period, yellowfin tuna decreased and the big-eyed tuna increased in number. Also, a comparatively large number of albacore, which are uncommon in the lower latitudes of island waters, were caught, and skipjack fishing was poor even at Truk and Ponape, just as it was at Palau. The increase in big-eyed tuna and the large catch of albacore meant low water temperatures in the surface stratum,

and the inactivity of skipjack at Truk and Ponape implied that the water temperatures at the surface were low. The author then surmised that the reason why the countercurrent area became unsuitable as a fishing ground for yellowfin tuna was the same adverse oceanographic conditions. Conditions in the waters adjacent to Palau have since been restored and it appears that, with the exception of the effect produced by bad weather, bonito fishing has become normal since the latter part of May. Skipjack fishing at Truk and Ponape also improved about the same period and the tuna fishing grounds centered at 150° also shifted northward. Consequently, it is believed that possibly the conditions in the countercurrent area centered at 150° are also restored, as in the adjacent waters of Palau.

From the above, it is believed that the slack in fishing resulting from the adverse conditions in the countercurrent centered at 150° is temporary. When oceanographic conditions are back to normal and fishing improves to its former level, it is proper from the standpoint of fishing management for the fishing ground to shift northward to the north latitudes. With fuel oil limited as it is today, the equatorial countercurrent, which is usually inhabited by a large number of yellowfin tuna, probably will hereafter show increasingly its true worth as the main tuna fishing ground in the Inner South Seas.

Report of
Oceanographic Changes and Fishing Conditions in Palau Waters

A tuna fishing survey of the seas south of the Palau group was conducted in conjunction with the oceanographic survey of the sea areas within a 600 mile radius of Palau from January to March of this year. As a result, our knowledge of oceanographic conditions in Palau waters has been clarified.

According to the results of the survey, the northern limit of the equatorial countercurrent area south of the Palau group (west of 134°30' east longitude), as compared to that of normal years, showed a southward shift of 0.5° to 1° so that the northern limit was at north latitude 5°30' or 6°. The southern limit west of 134°30' east longitude showed a southward shift of 1° so that it was at north latitude 3°. The southern limit east of 134°30' east longitude showed a shift of 1° to 2° so that it was at north latitude 2° or 1°. In short, the northern limit of the equatorial countercurrent area, which should be around 7°30' or 8° north latitude in the vicinity of 136° or 137° east longitude, shifted southward to about 6° north latitude. The western shores of the Palau group, therefore, were all exposed to the main current of the northern equatorial current. The northern equatorial current also flowed westward from the western shores of the Palau group to 130° east longitude without any penetration by the branch currents of the equatorial countercurrent. For this reason, all of the Palau Islands were in the northern equatorial countercurrent area.

When we studied the vertical distribution of water temperatures, we found that the surface temperature, which is closely related to skipjack fishing, in many places dropped to almost 27 degrees. From observations made on the Zuiho Maru during mid-February we discovered that at six out of seven stations the water temperature was down to almost 27 degrees or an average of 27.6 degrees. Observations made on the Arafura Maru (a chartered survey vessel) during early and mid-February disclosed the fact that two out of eleven stations had water temperatures of 26-27 degrees and seven had temperatures of 27-28 degrees. The average, similarly, was 27.6 degrees. This phenomenon was seen along the coast of the Palau group. The Hakuo Maru obtained a water temperature of 27.8 degrees during late February. On the other hand, according to the observations made on the Zuiho Maru during its later voyage (from late February to early March), the number of stations showing water temperature of 27-28 degrees diminished and those showing 28-29 degrees increased somewhat.

The occurrence of surface water temperatures of 27-28 degrees in Palau waters (north latitude 0°-10°, east longitude 128°-140°) cannot be called rare. According to the record of the periodic observations conducted at the mouth of Palau harbor during the six years period 1929-1934, these low water temperatures generally occurred every year. The occurrence sometimes covered the entire period from January to March and at other times was limited to a part of the period. This occurrence is extremely rare in the high seas. Furthermore, if it does appear, it is localized and does not extend over a wide area.

The water layer most closely related to the tuna fishery, judging from the mean depth of long line settings, was assumed to be at 100 meters, and the horizontal distribution of water temperatures at the 100-meter layer was determined. Of the ten stations located in the equatorial countercurrent area described above, there was only one which showed a water temperature of over 20 degrees, and that was 21.5 degrees. Others were all below 20 degrees and averaged 18.5 degrees. Of the 20 stations in the northern equatorial current, there were five whose water temperatures were over 20 degrees; these five averaged 21.5 degrees. The other temperatures were all below 20 degrees and averaged 17.8 degrees. Six stations which were assumed to be in the southern equatorial current all showed water temperatures of over 20 degrees; their average was 22.1 degrees. Three stations bordering the countercurrent and the southern equatorial current all showed temperatures of over 20 degrees; they averaged 22.4 degrees. According to these findings, practically all of the 100-meter layer of the equatorial countercurrent area showed water temperatures below 20 degrees and all of the 100-meter layer in the southern equatorial current showed water temperatures over 20 degrees. Furthermore, there were more stations in the northern equatorial current which had water temperatures of less than 20 degrees.

In order to understand the variations of the water temperature of this 100-meter layer, we made a rough study of the conditions existing during a normal year. In the northern equatorial current area, water temperatures below 20 degrees were occasionally found in the area near the shore, but the water temperatures in the high seas were from 22 to 27 degrees and only rarely below 20 degrees. Likewise, in the equatorial countercurrent area it rarely fell below 20 degrees and was from 23 to 28 degrees. The water temperatures in the southern equatorial current area were all above 20 degrees and averaged about 26 degrees.

In short, the water temperatures of the 100-meter layers in each ocean current recently showed similar drops. The drop was most noticeable in the equatorial countercurrent area, followed by the northern equatorial current area and the southern equatorial current area in that order. On the whole, there was a great change as compared to a normal year.

When the meaning of this change is considered in connection with fishing conditions, two points must be considered: the drop in surface water temperatures to 27-28 degrees in the coastal and high sea areas, and the drop in the water temperature of the 100-meter layer to below 20 degrees in the equatorial countercurrent area. (Yellowfin tuna, which are the largest element in the tuna catch, are more abundant in the equatorial countercurrent area than in the northern equatorial current area. Details concerning fishing conditions in the southern equatorial current are not as yet known.)

Next we studied fishing conditions in the coastal waters of the Palau group and sought their relationship with sea conditions. We first gathered the recent data on hand concerning skipjack fishing. The figures on the skipjack catch for January were set up and a comparison was made.

The exceptionally small catch for this year may be partly due, naturally, to the lack of live bait, but the major cause may be attributed to the fact that the water temperature dropped below 28 degrees. According to data from past investigations (see this Station's Oceanographic Survey Report Number 1), skipjack are not taken at water temperatures of 27-28 degrees.

Total Catch

Year	Month	Number of fish	Weight in kan*	Amount of catch per ship per day (in kan*)
1939	Jan	106,387	73,868	217
1940	"	106,982	97,570	448
1941	"	6,571	6,545	75

* 1 kan = 8.27 pounds

As previously explained, the eastern shores of the Palau group were washed by the main current of the northern equatorial current during January and February of this year and this type of ocean current was also seen in January and February of 1940. The good catch of skipjack during January and February of 1940 was explained by the belief that "abundant skipjack are found in the northern equatorial current". From the fishing conditions of this year, however, we learned that even though the shores are washed by the main stream of the equatorial current, skipjack cannot be found when the water temperature falls to 27-28 degrees (water temperatures in 1940 were over 28 degrees).

In regard to tuna fishing, the Zuiho Maru conducted operations at five stations in the equatorial countercurrent area during its two voyages at

which time the above-mentioned observations were obtained. Its total catch ratio (number of fish caught per 100 hooks) of tuna and sailfish averaged a mere 0.6; the maximum ratio was 1.7. This sea area, judging from past fishing survey results, has been an excellent tuna fishing ground, the operation results of the Zuiho Maru compiled during the period between November 1938 and March 1939 at 29 stations showing an average catch ratio of 4.4, with a maximum of 23.

The absence of tuna in the coastal waters of the Palau group was not only noticed during the fishing survey of the Zuiho Maru, but also appeared on the operation records of the medium-sized fishing vessels based at Palau. The figures obtained are as follows:

Year	Month	Average catch ratio per operation
1940	Oct.	3.7
	Nov.	4.9
	Dec.	4.1
1941	Jan.	2.3

Such poor tuna fishing results are believed to be mainly due to the fact that the temperature of the 100-meter layer of the equatorial countercurrent dropped below the minimum water temperature (20 degrees) suitable as a habitat for yellowfin.

When the equatorial countercurrent in the coastal waters of the Palau group shifts southward or when such a phenomenon as a drop in the water temperature of the 100-meter layer occurs, we should consider conditions in the countercurrent farther east.

We explained previously that when the current area shifted southward in December 1940, the countercurrent in the eastern area also shifted somewhat to the south as compared to that of the normal year (see South Sea Fishery News [Nanyō Suisan Jōhō], Vol. 4, No. 3). From the various data listed below, we can deduce that, as in the previous year, the current shifted southward and that the water temperature near the 100-meter layer also dropped.

(1) By studying the ocean current data obtained during tuna long line fishing tests in Palau waters by the Kiyo Maru (December 1940) and by the Kochi Maru (December 1940 to January 1941), the area of the equatorial countercurrent was found to be as follows. The northern limit of the area between 145° to 160° east longitude was roughly as shown on ocean current charts or around 6° to 7° north latitude, but the southern limit shifted southward 2° to 4° so that it was in 0° 30' north latitude.

(2) The average catch ratio of the Kochi Maru during November 1940 was 10.7, but even though it operated in the countercurrent area, its catch ratio from December 1940 to January 1941 was 2.9. (Surface water temperatures were over 28 degrees. No report on water temperatures of deeper layers.)

(3) Compilation of the monthly catch figures for South Sea tuna fishing vessels based at Misaki shows that the ratio of the number of big-eyed tuna to the number of yellowfin taken during November and December is 15 and 13 per cent respectively, and 38 per cent in January. (The habitable water temperature for big-eyed tuna is lower than that for yellowfin.)

The island fishing industry, which considers skipjack and tuna as its chief products, finds the phenomenon which results in the lowering of the surface water temperature to 27-28 degrees and the lowering of the 100-meter layer to below 20 degrees not at all to its liking, for this lowering of temperatures is unfavorable to the occurrence of these species. The cessation of this phenomenon at the earliest possible moment is hoped for by the industry.

The detection and clarification of the time of its cessation, the relationship between the southward shift of the equatorial countercurrent and the lowering of water temperature, and the cause of the lowering phenomenon are the problems left for future oceanographic study. To find an area which meets the requirements of good fishing conditions as to water temperature and other factors and which can serve as a good alternate fishing ground when the equatorial countercurrent, noted for its abundance of yellowfin, shows such a scarcity of fish, is the urgent and vital problem which is assigned to the fishing industry survey.

Addendum

Salinity

We did not touch on the subject of salinity in this paper because circumstances forced postponement of salinity determinations. The figures on salinities obtained by observation and recorded here are compiled according to ocean currents. A comparison is made of the vertical distribution of salinities for this year with those for 1940. The most noticeable differences were seen in the surface layer of the equatorial countercurrent and of the southern equatorial current, and in the 100-meter, 150-meter, and 200-meter layers of the equatorial countercurrent. The salt content of the surface water for this year was about 0.2 per cent higher, while on the other hand that of the middle layer for this year was from 0.2 to 0.4 per cent lower, with the difference of 0.4 per cent seen in the 150-meter layer.

In considering the relationship between salinity and the occurrence of yellowfin tuna, it is regrettable that we do not know the effect of lower salinity on the occurrence of the fish, but we assume that it adds somewhat to the effect of the lower temperature of the water centered around the 100-meter layer.

Report of a Survey of the Tuna Fishery in Palau Waters

This study was conducted during operations extending from April 7, 1941 to November 8 of the same year. The area studied was about 15 nautical miles off the eastern shores of Palau, bounded by north latitude 8° 0' to the north, east longitude 134° 53' to the east, north latitude 7° 6' 30" to the south, and east longitude 134° 28' 30" to the west.

The minimum surface temperature was 27.9° and the maximum temperature was 30.2°. The minimum temperature was 0.2° lower and the maximum temperature was 0.4° higher than the surface temperatures in the latter part of 1940. The water temperature 50 meters below the surface showed a minimum of 23.6° and a maximum of 29.4, with an average of 27.5°. The minimum temperature at 100 meters was 16.6° and the maximum was 26.2, an average of 20.8. Therefore, it indicated about 6.7° lower than the water temperature at the 50-meter stratum. However, since the hooks on the long line were suspended at a depth of about 50 meters, it may be safely said that the temperature most suitable for the yellowfin tuna during the course of this survey was 27°-28°. (The results showed the same temperature as that of the latter part of last year.)

Direction and Speed of Current

In the 11 experiments conducted, the current of No. 8 fishing ground, which showed the highest catch ratio of 14.16, flowed southwest at a speed of 0.6 knots. In fishing ground No. 11, with a catch ratio of 10.4, the current flowed to the southwest also at a speed of 0.5 knots. In fishing ground No. 9, with a catch ratio of 7.9, the current flowed to the southwest at a speed of 0.2. The currents of the fishing grounds which indicated good results during this period practically all flowed to the southwest and the speed averaged 0.5. The direction of the current was practically the same as that of the latter part of the previous year.

The Catch

In each case it was clear that the yellowfin tuna outnumbered the big-eyed tuna and the spearfish. As indicated in the fishing chart the yellowfin tuna in this period showed a particularly marked predominance compared to the latter part of last year.

Refer to "Oceanographic Changes and Fishing Conditions in Palau Waters" for the cause of the slack in fishing from April to June.

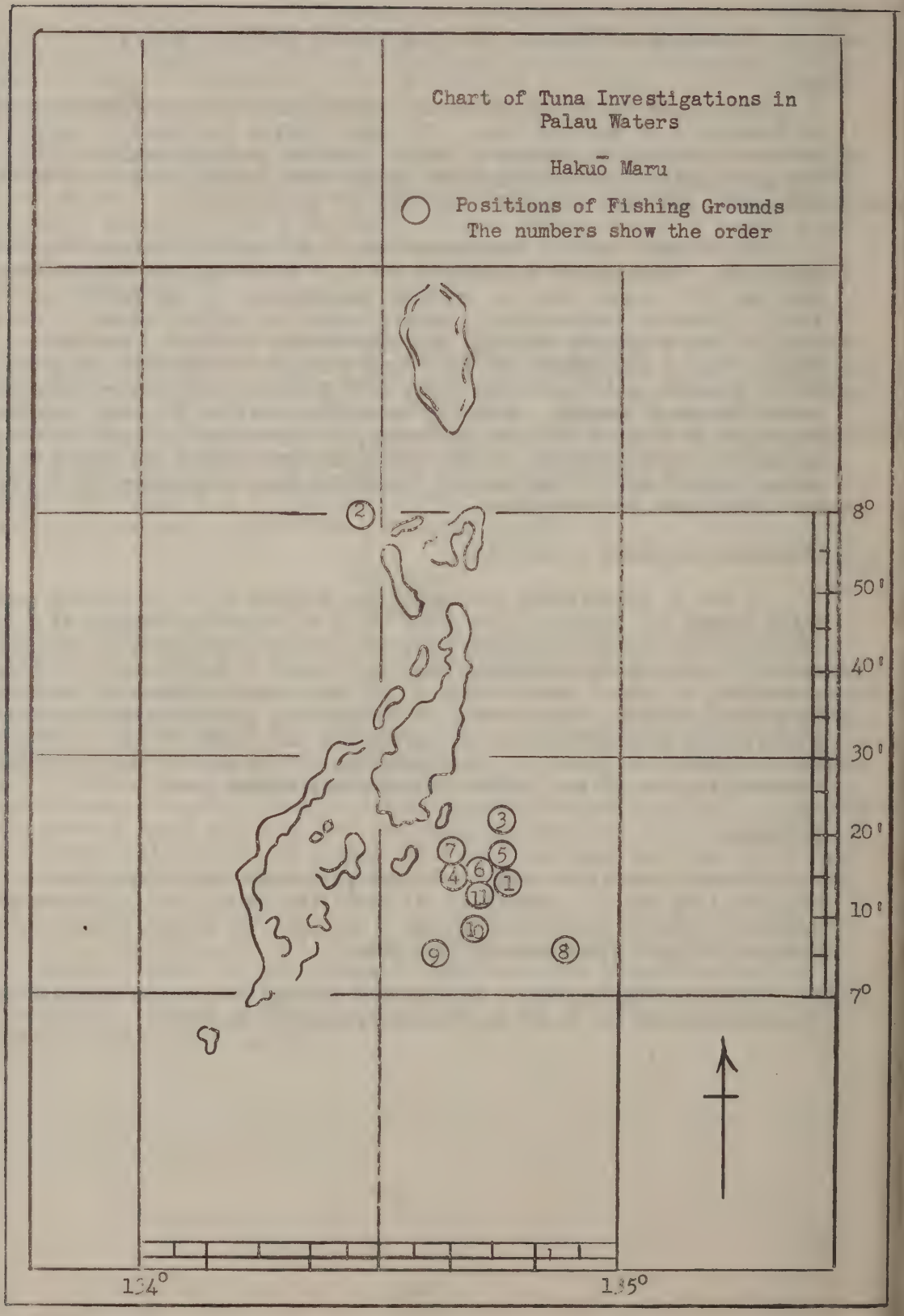
Chart of Tuna Investigations in
Palau Waters
Hakuō Maru
Positions of Fishing Grounds
The numbers show the order
8°
50'
40'
30'
20'
10'
7°
134°
135°

Water Temperature

No.	Surface water temperature	Water temperature 50m below surface	Water temperature 100m below surface
1	28.4	23.6	16.7
2	27.9	24.3	18.4
3	29.5	25.6	16.6
4	29.3	29.2	21.6
5	30.2	29.4	22.3
6	29.2	28.6	23.2
7	29.2	23.5	22.2
8	28.9	28.8	26.2
9	28.8	28.8	25.5
10	28.5	27.8	18.6
11	29.2	27.8	17.0

Survey of Tuna Fishing in the Seas Adjacent to Palau

No.	Date	Position of fishing grounds	Current direction	Current speed	Time line set Time line hauled	Number of baskets-hooks	Type of Catch	Tuna Catch
1	2 April	7°-15' N 134°-46' E	SW½S	1.6	6:00 AM 5:00 PM	40 240	-----	-----
2	12 April	8°-00 N 134°-28.5' E	NNE	1.0	5:30 AM 3:00 PM	" "	-----	-----
3	4 May	7°-20.5' N 134°-45' E	N/W	1.3	6:00 AM 3:35 PM	" "	yellowfin tuna medium -2	0.8
4	26 May	7°-15' N 134°-41' E	SW¼W	0.8	6:00 AM 5:00 PM	" "	yellowfin tuna medium -8 big-eyed tuna large -1	3.75
5	6 June	7°-17' N 134°-46.5' E	SW/W	1.6	6:00 AM 5:00 PM	" "	yellowfin tuna med-4 spearfish -1 shark -2	1.60
6	5 July	7°-16' N 134°-44.5' E	SW	1	5:50 AM 3:00 PM	20 120	-----	-----
7	8 July	7°-16' N 134°-39.5' E	SW/W	0.8	6:00 AM 2:30 PM	" "	-----	-----
8	10 October	7°-07' N 134°-53' E	SW	0.6	6:00 AM 4:00 PM	40 240	yellowfin -32 shark-eaten -2 skipjack -1 branch lines broken -2	14.16
9	13 October	7°-6.5' N 134°-39.4' E	"	0.2	5:50 AM 3:00 PM	" "	Med. yellowfin -16 shark -2 shark-eaten -3 skipjack -1	7.90
10	17 October	7°-9.5' N 134°-4.4' E	"	0.5	5:30 AM 4:30 PM	" "	Med. yellowfin -13 shark -1 shark-eaten -2	5.86
11	7 November	7°-20' N 134°-45' E	"	"	5:40 AM 4:30 PM	" "	Med. yellowfin -19 shark-eaten -3 large big-eyed -3 shark -1	10.40

[TN: The sections dealing exclusively with hydrography have been omitted from this translation.]

Fish Catch

Within the reefs carangids, isomaguro [Gymnosarda nuda ?], and sodagatsuo [Auxis thazard ?] are taken, but rarely. Outside near the barrier reefs tuna, skipjack, isomaguro, carangids, cybiids, and other miscellaneous fish are taken.

On virgin grounds, that is, at the beginning of fishing operations, fish were plentiful everywhere, but with the passage of years they appear to have become scarcer. It is thought that fishing has depleted the stocks of the fishes dwelling in shore waters.

The fishing is greatly influenced by weather, tide, and time of day. It appears that fishing is generally good in cloudy, rainy, or stormy weather, and that it is not good in clear weather when the sea is calm.

Fishing is best when the tide is rising.

Northern Fishing Grounds

Velasco and Ngaruangl reefs
Carangids, [illegible] [TN: species unidentifiable], and other miscellaneous fish were plentiful, and many bottom fish were taken by trolling.

Kayangel Channel
It was inferred that this is a good fishing ground from the numerous schools of skipjack and tuna found there.

Kayangel Island
Plenty of miscellaneous fish on the east coast; schools of pelagic fishes are seen off shore.

Northwest Reef, Cormoran Reef
Many tuna are taken near the seaward sides.

Kossol Reef and the reefs to the SE of it
Trolled here only a few times and caught few fish.

Central Fishing Grounds (West Side)
Ngamegei Passage -- West Passage
Schools of skipjack, tuna, and dolphin were seen over an area of several miles off this section.

Central Fishing Grounds (East Side)
Entrance to Ogedaobu Channel -- Malakal Passage
Many skipjack and tuna schools

Southern Fishing Grounds

Malakal Passage -- Denges Passage

Many skipjack and tuna schools

West of Auron Island

Many tuna and skipjack schools, many fish of all kinds taken by trolling.

Angaur Island

Many tuna off the west side

Peleliu Island

Skipjack schools are seen occasionally off the east side.

Southern Outlying Islands

Sonsorol Island

Large schools of skipjack and tuna are always present in adjacent waters.

Pulo Anna Island

Skipjack and tuna schools were sighted in the adjacent waters.

Merir Island, Tobi Island

As at Sonsorol, skipjack and tuna schools are always present.

Helen Reef

An extensive atoll reef; good catches were made trolling everywhere inside and outside the reef. Tuna are especially plentiful along the outer shores.

Bait Fish Investigation

Purpose

Bait is an important element in a fishery. In the skipjack fishery particularly, the abundance or scarcity of bait determines the development of the fishery, and therefore we made this survey following the investigation of the fishing grounds.

Methods

Bait fish appear to be plentiful everywhere inside the reefs at Palau, however, there are some species which occur only at certain places or at certain times. Since a detailed study requires a good deal of time, this investigation was carried on in conjunction with the experimental fishing operations.

Varieties of Bait Fish and Their Names

1. Herrings

katakuchi iwashi [may be Engraulis heterolobus]

There is a variety which is almost the same as that which occurs in Japan, and another in which the fins are red. They occasionally form large

schools and come inside the reef, but their grounds are not fixed and it would be difficult to take them at all times. They can sometimes be attracted with a light at night.

sappa

These fish are abundant within the reef, many schools especially occurring on sandy beaches where coconut palms grow. They can be taken with seines or throw nets. They will also gather around a light at night and can be taken by this method.

maru iwashi [may be Sardinella leiogaster]

These fish school in great abundance inside the reefs, and are attracted by a light at night. They can be taken with a stick-held dipnet or a set net [machiami]. It is possible to take them during the daytime, but it is difficult. This fish is very superior skipjack bait.

tōgoro iwashi [probably Atherina valenciennesii]

Occurs mixed with sappa everywhere inside of the reefs. They concentrate on sandy beaches or gather around a light at night and may be taken along with the sappa.

The species described above are taken well by the fish and are very suitable for use as bait, but they have the defect of being hard to keep alive with the methods used up to the present. If a study can be made of the methods of taking and holding them it should be possible to utilize them as bait on a large scale.

akamuro, shimamuro [probably caesionids]

The juvenile fish occur on the reefs (also outside the reefs) as non-migratory fish. They are excellent for bait from February to June, and can be used until August. They are comparatively easy to catch and survive well, but the mature fish are unsuitable for chumming bait. They can be used as bait during the several months when they are immature, and they are all right for bait until they reach a fair degree of maturity, but as they grow older they are harder to catch because they swim faster. The immature fish also form large schools out at sea and serve as natural food for the skipjack. In years when these schools are abundant many skipjack schools come in close to the barrier reef until about June and the fishing situation is very good.

akadoro, shiradoro [probably Chilodipterus spp.]

Ordinarily the red ones are given the common name of akadoro and the clear colorless ones are called shiradoro. These fish occur in large numbers on the reefs, and are so-called "reef fish". Their movements are slow, they are small in size, and they are easily taken.

During the day they hide in crevices in the reefs, becoming more active in the evening and at night, and returning to their holes early in the morning. When a net is put over the reef where they live about sundown and hauled the following morning when the fish are concentrated over the net after returning from their nocturnal food migrations, they can easily be taken. These fish are too small to be good for baiting hooks, but they are taken well by the fish and occur in the reefs the year round so they can be very well utilized when no other bait is available. These fish also survive well.

Other Miscellaneous Fish

All of the small fish and juvenile fish which occur in the reefs can be used as bait, but they are sparsely scattered and it is difficult to take them in large quantities.

Skipjack Investigation

Between September 1925 and the first half of 1926 the survey of fishing grounds was generally completed, and in November 1926 the investigation of the skipjack fishery was definitely begun.

Research Vessel

Hakuo Maru	11 tons	20 HP
Fishermen	13	

Fishing Gear

ordinary skipjack pole-fishing gear

Progress of the Investigation

The distribution of the schools, oceanographical conditions, and so forth could be inferred to be the same as in the previous year's investigation, but since this was the first study of the practical aspects of the fishery, it remained to be ascertained which of the fishing grounds were best.

January

We fished outside the Malakal Passage. Schools were fairly plentiful, but the northeast trades blew strongly and the weather was bad, making operations markedly unpleasant. Furthermore the color of the water was bad, the schools were swimming at high speed, and the fish took the bait very poorly. As a result we were not successful in our fishing. At first we took hira iwashi, akamuro, and akadoro inside Malakal Harbor for bait, but gradually bait became scarce in that area and we shifted our operations to the west coast, taking akadoro in the West Passage and the Arumonogui area. The area outside the passage was sheltered from the trade wind and the sea was calm. We sighted a fair number of schools, but they did not take the bait well and our catch showed no improvement. During the month we took only a little over 300 fish.

February

During the first ten days of the month the weather was bad and it was difficult to fish off the east side of the islands so we occupied the time chiefly in making a bait study inside the reef off Arakabesan. At the same time we went out to fish off West Passage, but we had to give this up because the NE trades were stronger than during the previous month, the sea was rough, and it was difficult to operate the boat. Consequently our catch during this period was almost nil, and in the second ten days of the month we sighted almost no schools. We caught fish only once off West Passage, and wasted a lot of time. During the last ten days of the month we did almost all of our fishing off the east side near the passage. Although the wind was still strong and the sea was still rough, we made fairly good catches. At that time the sea water temperature was around 28.5 degrees.

March

In the first ten days we centered our fishing operations around the vicinity of Malakal Passage. The schools were swimming fast and took the bait poorly. During the second ten days the weather was continually stormy and the schools disappeared so we made no catch. We made a bait survey around Ogurutaageru Passage and Denges Passage.

During the last ten days schools were numerous off the west coast and we took quite a few fish. As indicated above, the weather was bad during the period of the investigation, there were many storms, days of operation were few, and the results we obtained were not good.

Conclusions

This year's investigations, as indicated above, took few fish and did not produce the results anticipated because the personnel were inexperienced, unaccustomed to the fishing grounds, and not thoroughly familiar with the type of schools encountered. Furthermore, the weather was bad and it was not possible to operate as we had planned, however, schools were abundant and it can be hoped that in the future, with further experience and study, these fishing grounds can be fully developed.

Skipjack Fishery Investigation 1927

This investigation was a continuation of that of the previous year. Preparations were made during December of this year and operations were begun in January 1928.

Progress

January

The fishing ground was chiefly off Malakal Passage. The northeast wind blew continually, and rough seas made operating difficult. Schools were numerous, but they took the bait badly, and when they were swimming fast we were sometimes unable to hook any fish. Some catch was, however,

made on the majority of the days on which we fished. We fished from time to time in the West Passage area where the sea, being sheltered from the northeast wind, was comparatively calm and operating was easy, however, we sighted almost no schools and made no catch there during January.

The sea water temperature in both areas was about 28 degrees C.

Bait used was principally akadoro. These fish occur abundantly among the reefs around West Passage and Arumonogui, and are easily taken.

The places around Malakal Passage and the reef east of Airai village where these fish occurred in some abundance the previous year were wrecked by a great storm in May 1927 and none of these fish could be found there at all. It is thought that there is no prospect of taking bait along the damaged reefs until quite a few years have passed.

February

Fishing was very poor this month, almost no catches being made either off West Passage or off Malakal Passage. Consequently the time was spent mainly in bait investigations and in looking for schools. We went fishing all the way to Kayangel and Ngaruangl islands, but schools were scarce everywhere. We sighted skipjack schools on the east side of Kayangel Island and west of Northwest Reef, but made no catch. We were able to take bait in small quantities north of Arakelong village, but no akadoro were found around Ngaruangl and Kayangel islands, and we returned to port empty-handed.

March

We did not fish many days this month, but the schools gradually began to appear off West Passage and we made some catches in that area. Some fish were also taken off Malakal Passage.

We took bait at various locations but principally inside the reef near Arumonogui village.

Skipjack Fishery Investigations 1928

These investigations were carried on as a continuation of the previous year's work.

April

There were many calm days during this month and operating was easy. The sea water temperature rose to about 29 degrees C., and schools became more numerous in the West Passage area than on the east coast.

Baiting grounds were almost the same as during the previous month. The akadoro reappeared on the reefs where we had taken them during January and February.

May

We fished only a few days this month because of the pressure of other work, but the catch ratio was fairly good. Catches made during this month at the southern outlying island of Sonsorol using live bait brought down from Palau are thought to have provided especially good information in case the fishery is extended to the vicinity of that island.

To summarize, during the period of this investigation fishing was poorest in February, with March the second worst month, while January, April, and May were very good.

Bait used was chiefly akadoro; occasionally we used a light at night to attract iwashi which we took with a stick-held dipnet.

Iwashi are easy to take and the fish take them well, but they are hard to keep alive in pounds or in the bait-wells of the fishing boat, which causes difficulty in using them. If further study can develop suitable methods of capturing and holding these fish, it should provide the solution to the bait problem in this area.

As a result of this year's skipjack fishery investigations, the Okinawan fishermen, who until the beginning of this survey in January and February believed that the sampes which they had been using were the best kind of fishing boats, seeing the good results obtained by the research vessel quickly planned a powered fishing boat. Construction was begun in April and the boat began to fish in June. This construction of the first privately operated skipjack boat was the most effective result of our work.

Skipjack Fishery Investigations 1928

In the first part of this year the previous year's investigation was continued until May. The work was then discontinued and recommenced on January 14, 1929.

January

We operated during this month off Malakal Passage. The sea was rough, schools were scarce, the temperature of the surface water was low, and there were many days on which it was difficult to operate. We also fished outside West Passage where schools were more plentiful than on the east side (off Malakal Passage), the sea was calm, and our fishing was more successful.

As in the previous year, the bait fishing reefs on the east side were not yet recovered and bait was scarce.

February

During the first ten days we used iwashi as bait, taking them with a light and a stick-held dipnet in Malakal Harbor, but just as in the

previous year their use was a failure because almost all of them died in the bait tanks while the boat was under way.

In the second ten days we were forced to use only akadoro. We operated outside West Passage north of Konlei, and caught fish on three occasions. The fishing situation appeared fairly lively, but in the last ten days of the month almost no schools were sighted and fishing was in a sad condition.

Sea water temperatures were low this month, being about 27.5 degrees C. and occasionally lower than 27 degrees. It is worthy of note that fish were taken in this cold water, a phenomenon most unusual on South Sea fishing grounds.

The best fishing ground was the vicinity of Ngardman Passage.

March

In the first part of the month fishing was very good, and it got better and better during the middle of the month. The fact that large schools of skipjack were seen in the shore waters close to Palau where we had never encountered them previously is thought to have been due to the appearance both inside and outside the reefs of an abundance of juvenile akamuro, which are most excellent bait.

During the middle of the month, with bait (akamuro) plentiful and many schools coming in close to shore, we made good catches, but in the last ten days the schools gradually became scarcer and the fishing situation became dull, with only one catch made during the period.

In the first and second ten day periods of this month the sea water temperature was, as during the previous month, about 27.5 degrees C., in spite of which there were many schools of fish. In the last ten days the temperature rose to over 28 degrees C., a condition which was thought to be suitable for fishing, but contrary to our expectations the tendency was for the schools to disappear. In short, it is thought that the sudden rise in the surface temperature made the schools go down to the deeper levels where the temperature was lower.

Skipjack Fishery Investigations 1929

This was a continuation of the previous year's investigation.

April

During the first and second ten day periods of this month the fishing situation was extremely good, but during the last ten days catches decreased. The fishing grounds were almost all outside West Passage, and covered a broad area which had not been fished the previous year. Fishing was especially successful at this season between West Passage and Apura-shokoru I.

After the second ten days of the month the water temperature rose to 28.5 degrees C., and large skipjack appeared mixed with small tuna. The fish took the bait well. Almost all fishing was done out of West Passage in the area between Konlei and Apurashokoru I.

May

During the first ten days of this month we fished near Apurashokoru I., but after the middle of the month large schools of skipjack and tuna suddenly appeared outside Malakal Harbor, a phenomenon worthy of note, and the waters outside West Passage became rather inactive. Since the skipjack had begun to take the bait well it had become difficult to make good catches on artificial lures, but during this month more than 60 per cent of the catch was made with such lures.

The akamuro which we were using as bait were becoming larger and more difficult to catch, but they were, on the other hand, very effective as bait.

The water temperatures of 28.5 to 29.5 degrees C. were thought to be favorable for fishing.

The skipjack fishery investigations were discontinued as of this year.

The following is a brief summary of fishing conditions during this year. Sōdagatsuo [probably Auxis thazard] were plentiful, and although they were small, it is worthy of note that they were taken in waters of a low temperature. The bait fish akamuro were more abundant than in previous years and the skipjack schools came in large numbers. The baiting grounds were inside the reef near Apurashokoru Island and off Arakabesan. Large schools of akamuro were also seen occasionally swimming outside the reef.

These fish occurred both inside and outside the reef. After August they were mature and did not grow any more. Occasionally after August schools of juvenile fish which had been spawned at different times were seen, but they were of rare occurrence.

Good results have been obtained ever since the inception of this investigation, and three commercial boats have gone into operation, all of which have been successful.

Conclusions

A conclusive decision cannot be handed down on the basis of such a short-term study as this, but the results indicate that the general situation with regard to the skipjack fishery in Palau waters is as follows.

1. Weather and sea conditions and the skipjack schools

The skipjack are migratory fish which live in the open sea and follow warm currents. They form large schools in their food-hunting and spawning migrations. Leaving aside the problem of their spawning grounds, it is

certain that they come into the Palau waters in search of food. Consequently the most important consideration in this fishery is to learn the migratory pattern of the schools by a close study of the effects of weather and sea conditions on the abundance or scarcity of the food fish inhabiting the waters around the islands.

A comparison of the reports of the Meteorological Station and the results of our oceanographical observations shows that in the Palau area the year is in general divided into the season of the northeast trade winds and the season of westerly winds. The northeast trades blow continuously from November to April; in May and June the winds are unsettled, and westerly winds prevail from July to October.

From January to March the trade wind is strong, weakening somewhat in April, and the unsettled winds of May and June are generally weak.

2. Fishing season

The best season for skipjack fishing is when the trade wind starts to blow, that is, in November, December, and January. The decline which always sets in during February is thought to be due to the fact that water temperatures reach their yearly low in that month. The water temperature in February is 27 degrees C. It rains continually everywhere during the month and as the surface waters turn cooler the schools tend to disappear. The most favorable surface temperatures for the schools' activities are within the range of 28 to 29.5 degrees C., and although the situation varies from year to year (big catches were made in February 1929 in spite of rather low water temperatures), it seems that schools generally appear more abundantly as the water temperature rises. When it rains the temperature of the surface layer is lowered, the water color becomes bad, clarity is decreased, and the pattern of migration is disturbed, but the catch ratios under such conditions appear to be comparatively good. When the weather is clear and the sea is calm, the migrations of the schools are normal and operating is easy.

3. Fishing grounds

All of the waters around Palau can be said to be fishing grounds, but because of the configuration of the barrier reef, the ocean currents, and other factors, there are places where the fish regularly congregate and other places where they do not. Judging by the areas in which we have hitherto operated, generally every place around the Palau Islands can be called a fishing ground. During the trade wind season especially the schools tend to come in close to shore, while at other seasons they migrate several miles out to sea from the reef and operations are extremely easy.

Schools can also be seen 20 or 30 miles off shore, but as the investigation of the distant offshore grounds is as yet incomplete, the matter is left for further study.

4. Seasons of the year

During the periods in which we have made investigations hitherto it has been rather difficult to distinguish any definite seasons, but the weather throughout the year shows the following general divisions.

1. Period of seasonal winds

The northeast trades blow strongly from November to March of the following year. The sea on the east side is rough and it is difficult for fishing boats to operate, however, the west side is in the lee of the island and the waters near the barrier reef are calm, making operation easy.

2. Season of calms

The period from May to October is called the season of calms. Southwest winds blow but they are light and calm seas make navigation easy. However, the weather is extremely hot during this season.

3. Rainy season

Statistics show that the period from June to August is the season of greatest rainfall. The rainy season is accompanied by occasional sudden storms, and boat operation is difficult. During this season many schools appear in the upper layers and they take the bait comparatively well.

4. Dry season

The period of continuous sunny weather is called the dry season. Weather records show that days of clear weather and calm seas prevail from March to May. At this time boat operation is easy and bait is plentiful, making it a season of good catch ratios. All of the migrations of the schools appear to be for the purpose of spawning or finding food. The spawning grounds of the skipjack are assumed to be in warm waters, and judging from the condition of their reproductive organs, it appears that they come into Palau waters both to spawn and to hunt food. Consequently a tendency is seen for more skipjack schools to come into areas where bait fish are plentiful.

Observations

The following is a brief account of the experience of the fishermen who have, as a result of this skipjack fishery investigation, recognized the promising character of this fishery and begun to exploit it.

At Palau at present the Taiyō Fishing Company, Kamezō Uehara, and Katsutarō Tamagusuku are engaged in skipjack fishing. Teijirō Itagaki and two other persons are manufacturing dried skipjack sticks.

The Taiyō Fishing Company mainly buys fish which the natives at Sonsorol Island take by trolling from canoes and manufactures fish stick from it.

Kamezō Uehara received a subsidy from the Government-General in 1925 and operated a miscellaneous fishery, taking sōdagatsuo / Auxis thazard / inside the reef. Beginning in 1926 he planned a skipjack fishery using canoes, but seeing the results obtained by the Hakuō Maru, he received a grant-in-aid from the Government-General in June 1928 to construct a powered fishing vessel and began fishing for skipjack and manufacturing dried skipjack sticks. By March 1929 Tamagusuku and Kaneshiro's two boats had appeared and were fishing successfully.

A Tuna Survey in Palau Waters (Late 1940)

The report of the tuna survey in Palau waters conducted by the Hakuo Maru during early 1940 (April to September) was published in Volume 4, No. 6 of this journal; a report is hereby made on the later survey (September 1940 to March 1941).

This survey consists of 14 operations conducted from September 11, 1940 to March 17, 1941. The number of operations is the same as in the earlier survey. A very small area southeast of Palau bounded by north latitudes 7° 17' and 6° 49' and east longitudes 134° 44' and 134° 28' was surveyed. No investigation was made of the areas west or north of Palau. The results of the survey, here being generally the same as those obtained in the earlier survey.

The minimum water temperature at the surface was 28.1 degrees and the maximum was 31.4 degrees. The water temperature of the present survey was 3.7 degrees lower than the minimum temperature of the previous survey and 2.1 degrees lower than the maximum.

The water temperature at the 50-meter layer showed a minimum of 27.1 degrees, a maximum of 28.2 degrees, and an average of 27.7 degrees.

At the 100-meter layer the water temperature showed an average of 21.4 degrees with a minimum of 16.4 degrees and a maximum of 24.7 degrees. The water temperature at the 50-meter layer, therefore, is about 1 degree lower than the surface water temperature and at the 100-meter layer about 6.3 degrees lower than the 50-meter layer.

Since the tuna longline used in this survey was constructed to fish at the 50-meter layer, the water temperature suitable for tuna during this survey period is believed to be from 27 to 28 degrees.

Current direction and velocity

Of the 14 fishing tests conducted, the ninth fishing ground with the highest catch ratio of 9.44, showed a current direction of SW/W and a current speed of 0.75 knots. The next highest catch ratio of 5.41 is

shown by fishing ground No. 4 which had a current direction of SW and current speed of 0.25 knots. The third highest catch ratio of 4.44 is shown by fishing grounds No. 7 and No. 10 which had a current direction of WSW with a speed of 1.0 knot, and a current direction of SW with a speed of 0.3 knot, respectively. Of the fishing grounds which presented comparatively good results during this period, practically all showed southwest current direction and slow current speed of about 1 knot. The sea conditions of these grounds were generally the same as those encountered in the previous period.

Catch

The fact that more yellowfin tunas than big-eyed tunas and swordfish were caught shows a general similarity with the data obtained during the previous period.

During the previous period one albacore was caught from a current flowing SW. This is a peculiar phenomenon since another albacore was caught during the present period from a current flowing NE.

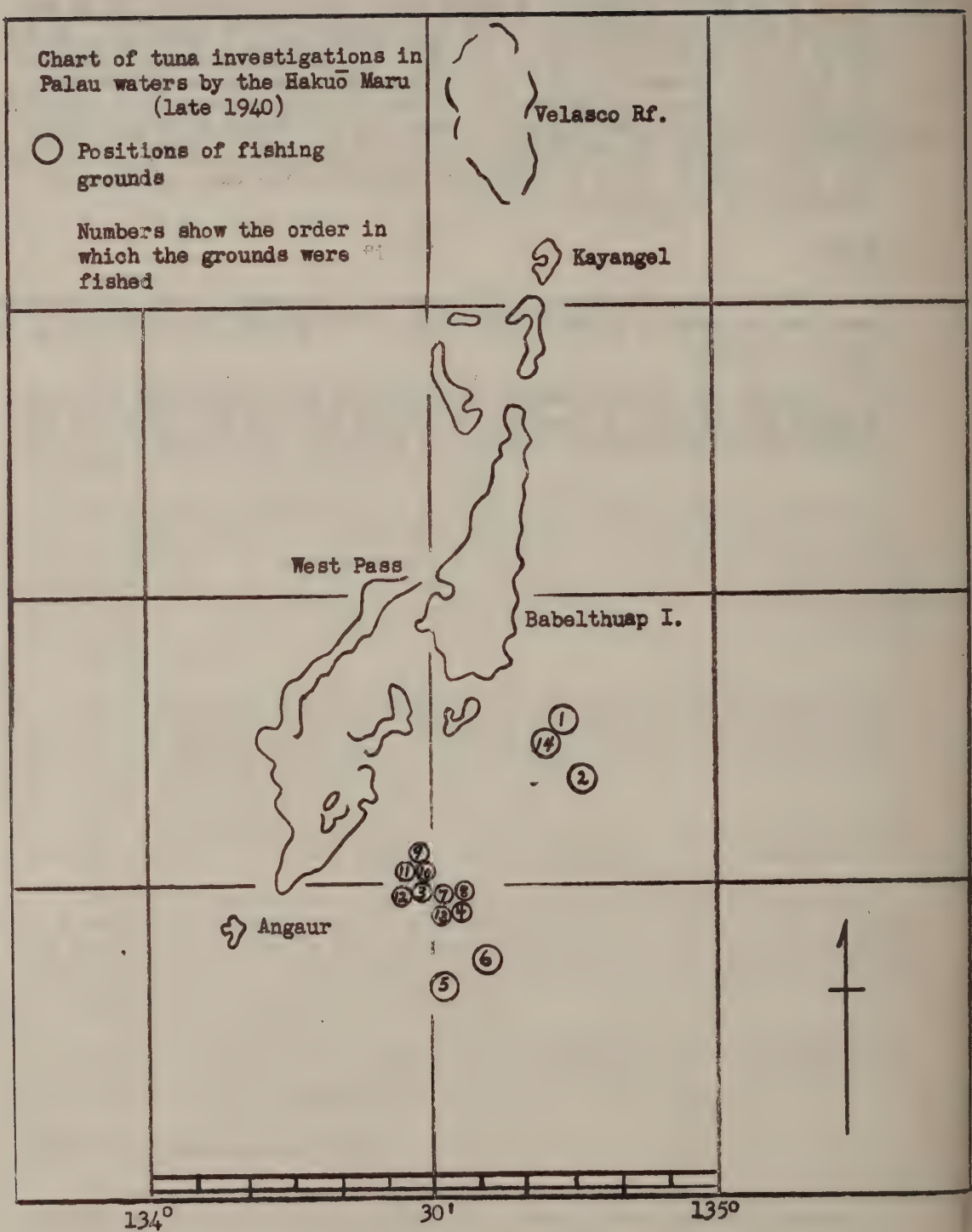
Chart of tuna investigations in Palau waters by the Hakuō Maru (late 1940)
Positions of fishing grounds
Numbers show the order in which the grounds were fished
Velasco Rf.
Kayangel
West Pass
Babelthuap I.
Angaur
134°
30'
135°

No.	Date	Ground Location	Current Direction	Current Speed	Time Cast Time Hauled In	Baskets Used	Hooks Used	Catch		Catch % (Swordfish Included)
		7°17'N			6:00 A. M.			yellowfin	4	
1	11 Sept.	134°44'E	NE	0.4	6:00 P. M.	40	240	albacore	1	2.08
								shark	5	
		7°12'N			6:00 A. M.			yellowfin	8	
2	1 Oct.	134°44'E	SE	0.3	5:00 P. M.	40	240	shark	3	3.33
		6°59'N			6:00 A. M.			yellowfin	4	
3	8 Oct.	134°29'E	SW	0.5	5:00 P. M.	40	240	swordfish	3	2.91
		6°56'N			6:00 A. M.			yellowfin	13	5.41
4	11 Oct.	134°33'E	SW	0.25	5:00 P. M.	40	240			
		6°49'N			6:00 A. M.			yellowfin	4	
5	26 Oct.	134°31'E	SW	0.5	6:00 P. M.	40	240	swordfish	6	4.16
		6°52'N			6:00 A. M.			yellowfin	9	
6	22 Nov.	134°36'E	W	0.32	6:15 P. M.	40	240	swordfish	1	4.16
		6°58'N			6:00 A. M.			yellowfin	7	
7	28 Nov.	134°31'E	WSW	1.0	3:35 P. M.	30	180	big-eyed tuna	1	4.44
		6°58'N			5:30 A. M.					
8	4 Dec.	134°31'E	SW	0.25	3:15 P. M.	30	180			
		7°03'N			6:00 A. M.			yellowfin	13	
9	13 Dec.	134°28'E	SW/W	0.75	3:30 P. M.	30	180	big-eyed tuna	4	9.44
		7°03'N			6:30 A. M.			yellowfin	4	
10	25 Dec.	138°28'E	SW	0.3	6:50 P. M.	30	180	big-eyed tuna	4	4.44
		7°02'N			5:00 A. M.			yellowfin	3	
11	9 Jan.	134°28'E	SW	0.75	4:00 P. M.	30	180	big-eyed tuna	1	2.22
		6°59'N			6:00 A. M.			yellowfin	5	
12	16 Jan.	134°29'E	SW/W	0.7	4:40 P. M.	30	180	big-eyed tuna	1	3.33
		6°59'N			6:00 A. M.			yellowfin	1	
13	19 Jan.	134°31'E	W 1/4 S	0.5	5:03 P. M.	30	180	shark	1	0.55
		7°15'N			6:00 A. M.			yellowfin	1	
14	17 Mar.	134°43'E	SW/S	1.4	5:20 P. M.	40	240			0.41

Water Temperature

No.	Water temperature at surface	Water temperature at 50-meter layer	Water temperature at 100-meter layer
1	28.1	28.2	23.1
2	28.2	28.2	24.4
3	28.2	28.2	22.2
4	28.3	28.2	24.7
5	29.4	28.8	24.4
6	29.8	28.0	21.2
7	29.4	28.8	22.8
8	29.3	27.1	21.8
9	29.0	26.4	21.2
10	28.7	28.4	21.4
11	28.5	24.0	18.4
12	28.7	28.5	16.4
13	28.7	28.1	17.0
14	28.2	27.8	20.7